US005295243A

United States Patent [19]

Robertson et al.

[11] Patent Number: 5,295,243

[45] Date of Patent: Mar. 15, 1994

[54] **DISPLAY OF HIERARCHICAL THREE-DIMENSIONAL STRUCTURES WITH ROTATING SUBSTRUCTURES**

[75] Inventors: **George G. Robertson; Jock Mackinlay**, both of Palo Alto; **Stuart K. Card**, Los Altos Hills, all of Calif.

[73] Assignee: **Xerox Corporation**, Stamford, Conn.

[21] Appl. No.: **66,311**

[22] Filed: **May 21, 1993**

Related U.S. Application Data

[63] Continuation of Ser. No. 795,238, Nov. 15, 1991, abandoned, which is a continuation of Ser. No. 454,010, Dec. 29, 1989, abandoned.

[51] **Int. Cl.**[5] **G06F 15/00**

[52] **U.S. Cl.** **395/160**

[58] **Field of Search** 364/518, 521, 522, 146, 364/147; 395/120, 137, 160, 152; 340/721, 729, 734

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,434,460	2/1984	Drakenborn et al.	364/200
4,613,946	9/1986	Forman	364/518
4,649,499	3/1987	Sutton et al.	364/518
4,710,763	12/1987	Franke et al.	340/723
4,742,558	5/1988	Ishibashi et al.	382/56
4,752,889	6/1988	Rappaport et al.	364/188 X
4,764,867	8/1988	Hess	364/200
4,794,528	12/1988	Hirose et al.	364/300

(List continued on next page.)

FOREIGN PATENT DOCUMENTS

309374A	3/1989	European Pat. Off. .
323302A	7/1989	European Pat. Off. .

OTHER PUBLICATIONS

Fairchild, K. M., Poltrock, S. E., and Furnas, G. W., "SemNet: Three-Dimensional Graphic Representations of Large Knowledge Bases", in Guindon, R., Ed., Cognitive Science and its Application for Human Computer Interaction, Lawrence Erlbaum, Hillsdale, N.J., 1988, pp. 201-233.

(List continued on next page.)

Primary Examiner—Mark K. Zimmerman

[57] **ABSTRACT**

A processor presents a sequence of images of a hierarchical structure that is perceived as three-dimensional. The hierarchical structure includes conic substructures that can have vertical or horizontal axes. Each cone has a parent node at its vertex and children nodes along its base, each with a link to the parent node. Each child can in turn be at the vertex of another cone. The cones can be rotated in steps that produce the perception of object constancy for each node. For example, if the user requests that an indicated node be moved to a primary viewing position, each of the cones along the path from the indicated node to the root node is rotated in the direction that most directly moves the indicated node to the primary viewing position. Each node can include a selectable unit for indicating it, and a node can also include a grow tab that can be selected to request presentation of its children nodes and links to them. The user can request that the children nodes of a node be replaced by a grow tab. To reduce the computation necessary for each step of rotation, the position relative to a cone's axis for each of 80 points on the base of a cone is computed for a level of the hierarchy and is then stored in an array for subsequent use in positioning nodes on that level. The base point of each node on a rotating cone can then be changed in a linked node data structure, and its new position can then be obtained by simple arithmetic operations using the axis coordinates and the appropriate data from the array. The base of each array can be a polygon whose vertices are nodes, and the base shape can be presented as a shadow to provide additional information and strengthen the perception of three dimensions. Or, the profiles of the cones can be presented as a shadow.

22 Claims, 16 Drawing Sheets